Active Feedback Mirror System for the IR Beamline 1.4.x Complex

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INTRODUCTION

The IR beamlines, due mainly to the interferometric selection of wavelength, have proven to be the most sensitive to microscopic motions of the ALS beam. Even after a long series of beam noise abatement projects in collaboration with ALS accelerator and engineering staff,[1-4] the IR photon beam still moves in angle with an rms magnitude of a few microradians. This motion, because of the small (0.25 mm^2) size of the IR detectors, and the nature of the FTIR data reduction places noise in the IR spectrum which manifests in two modes. The exact frequencies of the noise are reproduced in the spectrum as a function of the scanning mirror speed in the interferometer, and all frequencies of the noise contribute to an overall background noise. The higher frequency noise, particularly in the 4 to 8 kHz region has been largely eliminated by changing out the 500 MHz master oscillator which drives the RF cavities to a more quiet unit. Despite large improvements to the low frequency noise in our spectra coming from the vibrations of pumps and other sources on the ALS floor, there remains some noise on the photon beam in the sub-acoustic (<500Hz) region which is detrimental to the overall signal to noise. To reduce this beam motion an active optical feedback system was designed and is being implemented. We report preliminary results using a single two-axis feedback loop.

TECHNICAL DETAILS

Conversations with M. Melczer of Lawrence Livermore National Lab (LLNL) indicated that an existing system used at LLNL was capable of attaining good correction in beam motion up to ~1 kHz without overheating the piezoelectric (PZT) elements. LLNL provided suggested position sensitive detectors and tip/tilt mirror stages along with the circuit parameters modeled with a Simulink™ program. We purchased Hamamatsu S1880 two dimensional position sensitive detectors with matching signal conditioning electronics. These circuit boards provide two low impedance signals which locate the centroid of a visible beam of sufficient intensity to approximately 1 μm, and a similar signal which is proportional to the total intensity. These detectors do not have a dead region along the axes or in the center of the detector. To move the beam in response to the detector signals we purchased Physik Instrumente S-330 two axis PZT tip/tilt stages. These stages operate on relatively low voltages of 0-100 Vdc. Experiments to date indicate that only a small subset of the voltage range provides sufficient angular correction in our application, and that we have sufficient visible intensity. Dichroic beamsplitters were purchased from Spectra-Tech which reflect nearly 100% of the infrared light, but allow approximately 50% of the visible beam to pass through. The circuit was designed and constructed on a custom card and placed in a “NIM” bin. Enough cards were manufactured for backup purposes and for future ALS IR beamlines. (Other synchrotron labs have expressed interest in the designs, pending final results.)

PRELIMINARY RESULTS

We tested the concept using one detector and tip/tilt stage and two feedback loops in x and y corresponding to the #1 mirror, and #2 PSD positions in Fig. 1. This is not expected to pin the beam in angle and position at the microscope since two more degrees of freedom exist. However it does lock the beam position within the dead band of the system on the PSD #2. Fig. 2 shows the power spectrum of 1 channel of the position readout from the PSD electronics with and without the feedback. A significant stabilization of the beam position is demonstrated.

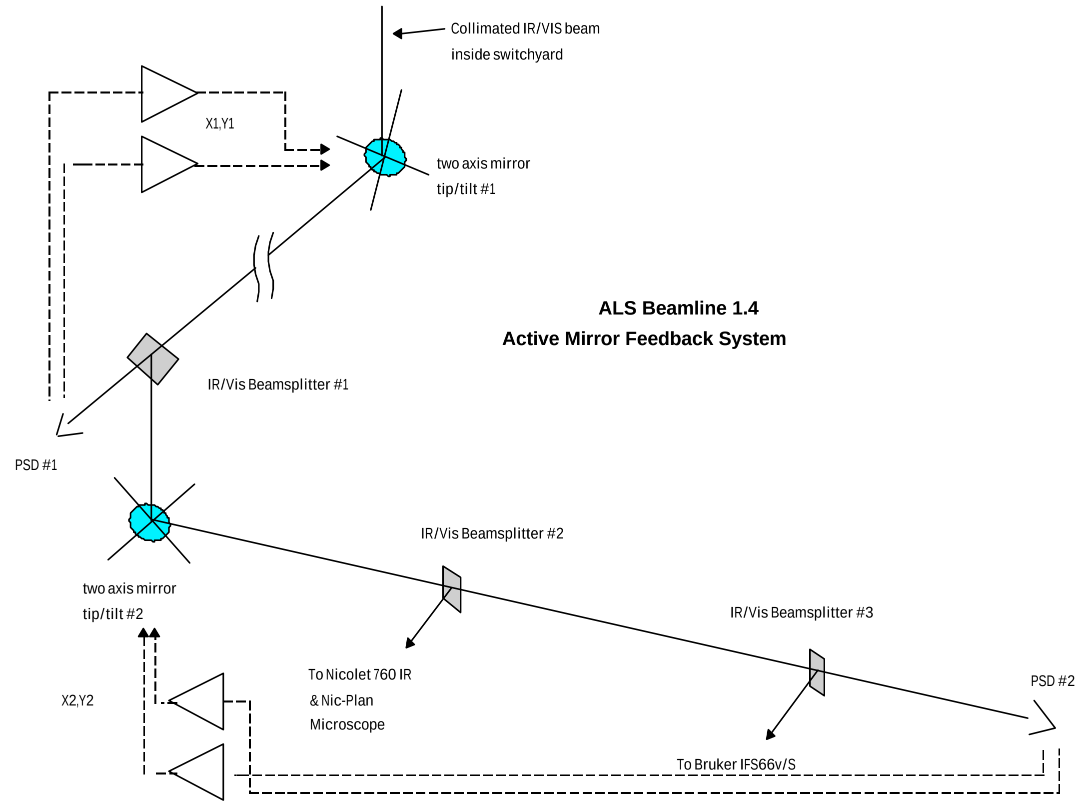

Figure 1. Schematic diagram of the planned optical active feedback system for the Beamline 1.4 complex. It consists of four feedback loops to lock the photon beam in x, y, θ, and ϕ.

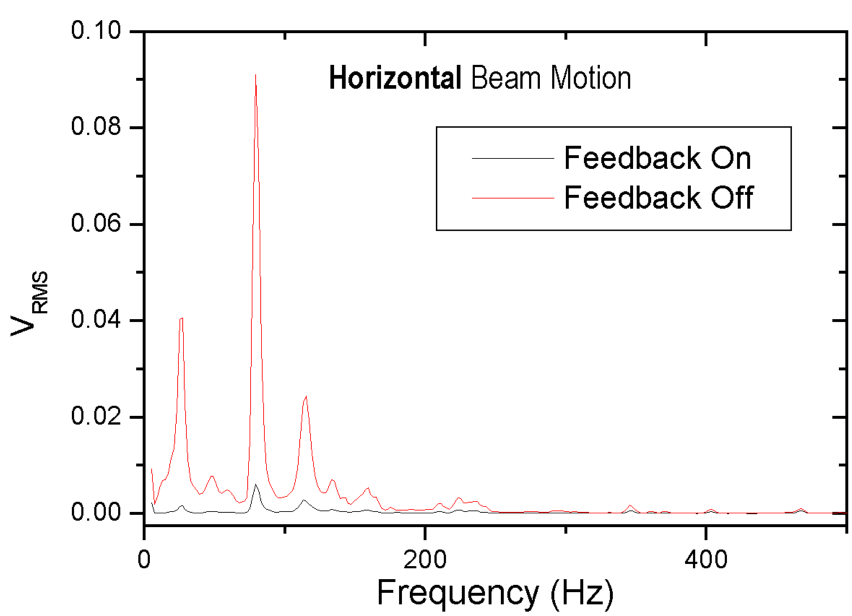

Figure 2. Measured noise spectrum at the first Hamamatsu detector with and without one feedback loop on. The largest vibration at 80 Hz is reduced by a factor of 15.

PLANNED IMPLEMENTATION

We are presently installing and testing the full four-loop feedback system into the beamline as shown in Figure 3. We anticipate a significant reduction in the signal to noise ratio in the measured FTIR spectra.

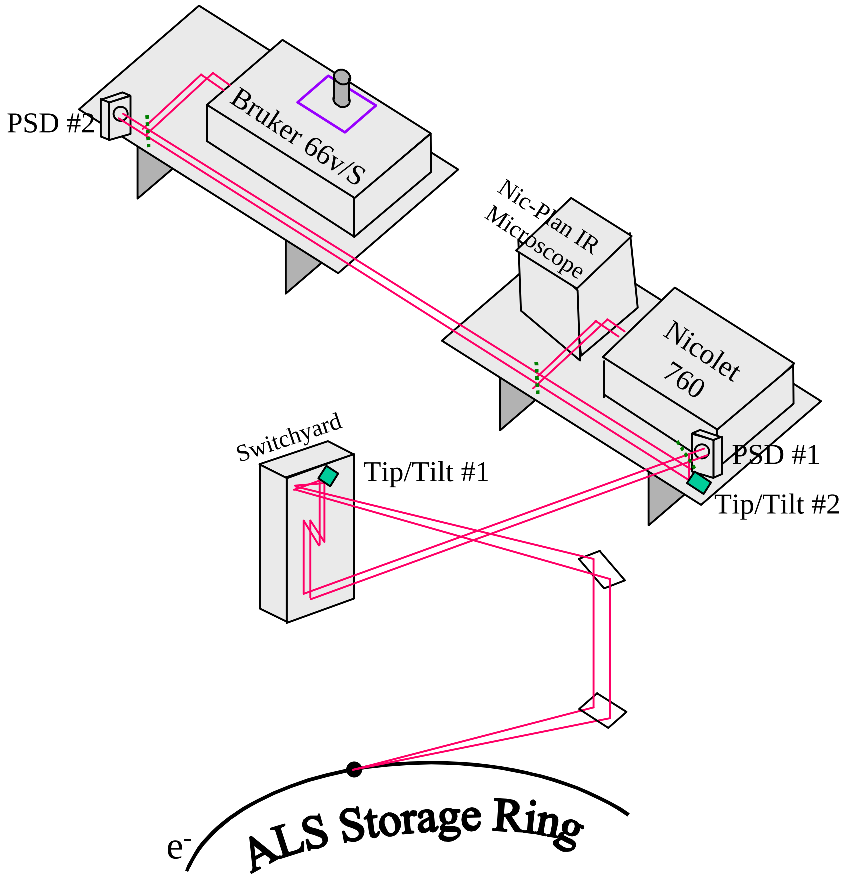

Figure 3. Drawing of the planned feedback system installation at Beamline 1.4. The first PZT driven tip/tilt mirror is installed inside the switchyard. A beamsplitter will allow a portion of the visible light to shine on the first Hamamatsu PSD, the readout of which will be fed back to the active mirror in the switchyard. A second active optic will be installed just below the beamsplitter, the same distance from it as PSD #1. This second active mirror will be controlled by the signal coming from PSD #2. This configuration will allow a stablized beam to be used for both the Nicolet system of BL1.4.3, and the Bruker system of BL1.4.2.

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